James Acker:
Sarah's WebEx connection didn't work, so she's presenting as me (James Acker).

Welcome, Sarah.

Sarah Strode:
Hello everyone

This presentation describes a study on the emissions and transport of the radionuclide cesium-137 (137Cs) from boreal biomass burning in the summer of 2010. The summer of 2010 was an intense wildfire season in western Russia. The figure below, created in Giovanni, shows aerosol optical depth (AOD) over this region from the MODIS instrument averaged over July 14 through August 14 of 2010. Aerosol emissions from biomass burning (BB) led to the high values of AOD shown in the figure.

Cs-137 is a radionuclide with a 30-year half-life. It's concentrations peaked in the 1960s due to nuclear weapons testing, with the largest deposition occurring at the latitude around 45 degrees north. The Chernobyl accident introduced additional source of Cs-137 to the environment in 1986. The concentrations of Cs-137 subsequently decreased over time, and by 2010 the atmospheric 137Cs concentration was typically below the detection limit. However, 137Cs is persistent in northern ecosystems, and can be released back into the atmosphere during boreal fires. The Fukushima accident in 2011 released a large amount of Cs-137 into the environment, but our study predates that event.

Wotawa et al. [2006] examined Cs-137 measurements from Yellowknife, Canada, and found that the elevated concentrations in the summers of 2003 and 2004 (blue line on the top figure) could be explained by biomass burning in Russia (yellow line) and North America (teal line), respectively. They estimated Cs-137 emissions based on fire pixel counts from the MODIS satellite, shown in the top figure. This study established that long-range transport of biomass burning emissions could influence Cs-137 concentrations.

MODIS fire counts also show high values for the summer of 2010 in western Russia (bottom figure). Consequently, we examine whether these wildfires led to observations of elevated atmospheric Cs-137 concentrations. Cs-137 is measured at radionuclide monitoring stations by the CTBTO. Since Cs-137 levels were typically below the detection limit, most stations have few detections. Consequently,

we focused on 2 stations: the Yellowknife, Canada station and a station in Dubna, Russia. The locations of these stations are shown in the figure in the bottom right. The Dubna station is located near the region of intense 2010 biomass burning.

Since observations of Cs-137 are sparse, we would like to relate Cs-137 concentrations to a more widely observed quantity. Cs-137 emitted to the atmosphere by biomass burning binds to aerosols. Consequently, satellite observations of aerosol optical depth can provide a global-scale context for Cs-137 observations. We obtained MODIS AOD data from Giovanni for the areas around Yellowknife and Dubna, and compared the AOD (black lines and axis) for each day in the summer of 2010 to the observed Cs-137 concentrations (red dots and axis). Although Cs-137 is typically below the detection limit (~2 micro-Bq/m3), detections occurred at Dubna on numerous days during the wildfires. The figures show that days with high Cs-137 values typically have high AOD as well. This makes sense because smoke from biomass burning contributes to high levels of aerosols.

Next, we simulated the transport of Cs-137 in an atmospheric general circulation model, GEOS-5, to help quantify the sources of the observed Cs-137. Since Cs-137 is transported in particulate form, we use the GOCART aerosol model within GEOS5 to simulate Cs-137 by assuming a ratio between Cs-137 and particulate organic matter. We used biomass burning aerosol emissions from the GFED3 inventory, but adjusted them upwards over western Russia to better reproduce the observed AOD. We then regressed the model's particulate organic matter concentrations at Dubna against the observed Cs-137 concentrations to estimate the 137Cs/organic carbon emission ratio.

Although we have assumed a constant ratio of 137Cs to organic carbon, this may not be a good assumption since the level of Cs-137 varies greatly between regions. The figure shows the spatial variability in Cs-137 deposition over Europe. Consequently, we include “tagged tracers” in our model that track the transport of particulate matter from biomass burning in specific regions. This allows us to test whether the observed Cs-137 is most correlated with biomass burning in general or with burning in a particular region. We include tagged tracers for boreal biomass burning (all BB north of 40 degrees), North American BB, western Russian BB, BB from 40-50 degrees north, and two smaller regions located southwest and southeast of Moscow that show higher levels of Cs-137 on the map.

The AOD from MODIS (top left figure) shows high values extending across western Russia. The Dubna site (blue D) is located within the high aerosol region, showing that it is impacted by the wildfires. The Yellowknife station (blue YK) is located in the region of high AOD in Canada. The model reproduces the AOD peaks in both these regions, although the magnitude is somewhat underestimated (top right). The black boxes in the top right figure show the regions

for the southwest and southeast tagged tracers described on the previous slide. The bottom left figure shows the model AOD only in regions that have a MODIS retrieval for easier comparison with the MODIS plot. The figure in the bottom right shows the contribution of the boreal BB particulate organic matter tracer to the AOD. This tracer has the same spatial pattern as the high values in total AOD, confirming the importance of the biomass burning source for these regions.

These figures compare the modeled Cs-137 from each of the tagged regions (scaled to fit on the same axis) to the Cs-137 observations at Dubna and Yellowknife. At both sites, modeled Cs-137 from boreal biomass burning (red line) reproduces the timing of many of the Cs-137 observations, although there are some errors in the magnitude. At Dubna, the western Russian BB (light blue dashed line) dominates the BB source, while at Yellowknife the North American BB (dashed green line) dominates. Regressing the model tracers against the observations, we find that boreal biomass burning explains approximately half the variance in the daily Cs-137 concentrations. The highest correlation at Dubna is found for the tagged tracer representing the southeast region, while there is no significant correlation for the southwest region.

Since the previous slide showed a strong correlation between observed Cs-137 and the tracer for biomass burning in the southeast box, we focus further on that region here. The bar graph shows the organic carbon (OC) emissions from the GFED3 inventory in the southeast and southwestern boxes for 1997 to 2010. It shows that the emissions from the southeast box in 2010 far exceeded the emissions in previous years. Also, the 2010 organic carbon emissions from the southeast box greatly exceeded those of the southwest box, which helps explain why the southeast box had the higher correlation with the Dubna observations even though there is higher Cs-137 contamination in the southwest box.

The highest correlation for the southeast box is also consistent with other studies of the 2010 wildfires. For example, the bottom figure, which is from a paper by Witte et al. [2011], shows satellite observations of fires southeast of Moscow (bottom right) and trajectories during the late July wildfire period reaching Moscow from the southeast (bottom left).

We also use the model to examine how the transport and subsequent deposition of Cs-137 from the wildfires redistributes Cs-137 to different regions. The top figure shows the model's net surface flux of Cs-137, the deposition minus the emission. The negative flux is (blue and green colors) is concentrated in relatively small emission regions, while the positive flux is distributed more broadly. The bottom figure shows the latitudinal distribution of the emissions (black line) versus deposition (gray line). The deposition extends further north than the emissions, showing that the net effect of the fires was to redistribute Cs-137 northward. However, the values of these fluxes

are quite small compared to the existing levels of surface Cs-137.

In conclusion, we found that detections of Cs-137 were correlated with aerosol optical depth at two high-latitude sites during the summer of 2010 biomass burning. We used the relationship between Cs-137 and aerosol observations to model the particulate transport of Cs-137 from biomass burning and to estimate that approximately 1.5x1012 Bq of Cs-137 were emitted during the summer of 2010. We find that this led to a small northward redistribution of Cs-137. Giovanni was useful for extracting MODIS AOD data for the sites of interest.

Are there any questions?

James Acker:
Jim asked where the wind fields come from.

Amanda Truett:
And... where those 7-day back trajectories?

Sarah Strode:
The meteorology for our model came from the MERRA analysis

I'm not sure about the back trajectories in the Witte et al. paper

James Acker:
OK, thank you again, Sarah. Giovanni has provided a number of really good images of smoke aerosols from fires - interesting to see the geophysical impact of the fires illustrated.